Properties of Some Common Newfoundland Forest Soils and their Relation to Forest Growth

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The morphological, physical, and chemical properties of nine, important, broadly defined Newfoundland forest soil types are described in this paper. The soils of the Avalon Peninsula are generally stonier, more compacted, and richer in silt and clay than those of western Newfoundland. Gleysols and gleyed podzols are the common soils on the Avalon Peninsula whereas orthic and peaty podzols are the common soils in western Newfoundland. In both sample areas the growth of balsam fir and black spruce stands is best on brunisols and poorest on gleysols and deep peats. Only a very small proportion of the total nutrient supply in the various soils is in an available form, but amounts are considered adequate to maintain the nutrient cycle and its associated forest growth at their present levels more or less indefinitely, provided there is no severe disturbance involving the permanent removal of some of the available nutrients. To achieve lasting increases in forest productivity it will be necessary to increase the rate of nutrient cycling by appropriate cultural treatments.

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Cet article décrit les caractères morphologiques, physiques et chimiques de neuf types importants de sols forestiers de Terre-Neuve. Les sols de la péninsule d'Avalon sont en général plus pierreux, plus compacts et plus riches en limon et en argile que ceux de l'ouest de Terre-Neuve. Les gleysols et les podzols gleyifiés sont dominants dans la péninsule d'Avalon tandis que les podzols orthiques et les podzols gleyifiés sont communs dans l'ouest de Terre-Neuve. Dans les deux régions, la plus forte croissance des peuplements de sapin baumier et d'épinette noire est observée sur les brunisols; elle est par contre très faible sur les gleysols et les sols organiques profonds. Une faible proportion seulement des éléments nutritifs dans les divers sols est sous forme disponible mais les quantités sont considérées suffisantes pour maintenir, plus ou moins indéfiniment, le cycle des éléments nutritifs et la croissance des arbres aux niveaux actuels, pour autant qu'aucun dérangement sévère n'occasionne l'enlèvement permanent de certains des éléments disponibles. Pour atteindre à un accroissement persistant de la productivité forestière, il sera nécessaire d'accroître la vitesse de mise en circuit des éléments au moyen de traitements culturaux appropriés.

Introduction

Very little information is presently available on the morphological, physical, and chemical properties of most of the common Newfoundland forest soils. Such information is, however, necessary as a basis for the logical development of studies into tree–soil interrelationships and for the development of effective and biologically sound forest management techniques for improving site and stand productivity.

In 1968 a study was started on the Avalon Peninsula and in western Newfoundland to investigate interrelationships between soil and topographic conditions and the height growth of stands of balsam fir (*Abies balsamea* (L.) Mill.) and black spruce (*Picea mariana* (Mill. B.S.P.)). These two sample areas were selected because of the large differences between them in climate, geology, topography, and forest history. As part of the study, much information has been gathered on the properties of nine, important, broadly defined forest soil types of the two areas.

These data, which are not incorporated in any previously published material, are presented in this paper as an initial step in the characterization and evaluation of these soils with regard to tree growth. The soil types that are described are essentially analogous with the soil great groups or subgroups as defined by the National Soil Survey Committee of Canada (Anonymous 1970), but with some modifications according to the importance of the various types to forest growth in Newfoundland.

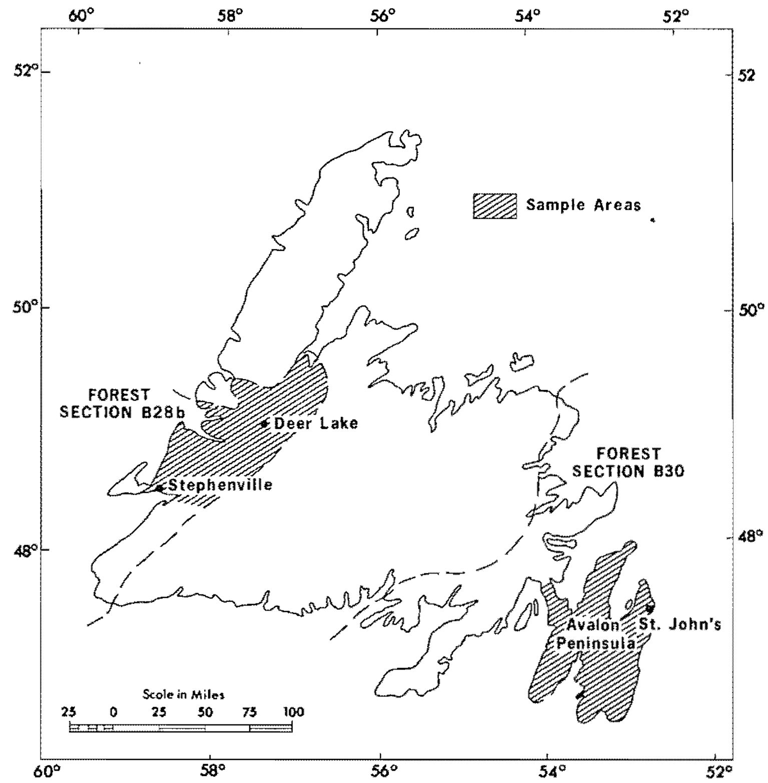

FIG. 1. Island of Newfoundland showing sample areas.

Methods

In western Newfoundland, sampling was confined to the northern two-thirds of forest section B28b of the boreal forest region (Rowe 1959); the Avalon Peninsula sample area forms part of forest section B30 of the boreal forest region in eastern Newfoundland (Fig. 1). A total of 150 soils (75 under stands of balsam fir and 75 under stands of black spruce) were sampled in each of the two areas. Circular, $\frac{1}{10}$-acre (0.04-ha) plots were established only in well stocked, mature and semimature stands, on a wide range of sites.

Locations were selected to cover the complete range of productive forest sites and as wide a range as possible of each of the major site characteristics including elevation, aspect, topographic position, site and profile drainage, and profile morphology. There was no selection for the more detailed soil characteristics such as texture, nutrient status, and moisture retention, and these were therefore effectively sampled at random.

All trees of 0.5 in. (1.27 cm) d.b.h. and above were tallied in each plot, and the heights and breast height ages of four, well formed dominant trees recorded. A soil pit was dug beneath the crown of one or more dominant trees and a record was made of the total depth to bedrock or impenetrable compacted till layer, the depth of all horizons including the organic mantle, the profile drainage class, and the depth of freely drained soil above gleying (when present). A preliminary classification of each soil was then made on the basis of these morphological characteristics.

Sampling was confined to the upper 12 in. (30 cm) of the soil profile (excluding the L and F layers) since below this depth profile development is usually minimal and conifer roots are scarce. Three samples (each containing soil from all sides of the soil pit) were collected from each profile, air-dried at about 30 °C, passed through a 2-mm sieve, and the following properties determined:

(1) Percent sand (0.05 to 2 mm), silt (0.002 to 0.05 mm), and clay (less than 0.002 mm) by the standard hydrometer method.

(2) Percent small stones (larger than 2 mm and smaller than approximately 3 cm, *i.e.* the diameter of the soil core sampler used, in at least one dimension).

(3) Bulk density (including small stones as above).

(4) Percent moisture retention at $\frac{1}{3}$ and 15 atm pressure, determined using a pressure membrane apparatus.

(5) Color readings of hue, value, and chroma for air-dry samples, by comparison with a soil color chart (Munsell Soil Color Co. Inc. 1954).

(6) Percent loss of weight on ignition, as an approximate measure of organic matter content by heating in a muffle furnace at 475 °C for approximately 16 h.

(7) pH by the sticky point method (Jackson 1958).

(8) Total nitrogen by the standard Kjeldahl distillation method (Jackson 1958).

(9) Available phosphorus, extracted with dilute sulfuric acid, determined by the 'molybdenum-blue' method (Truog and Meyer 1929).

(10) Available calcium, magnesium, potassium, and sodium, by extraction with ammonium acetate solution (Scollenberger and Simon 1945), and determination using an atomic adsorption spectrophotometer.

(11) Carbon–nitrogen ratio of humus (carbon content = percent loss on ignition × 0.59 (van Bemmelen's factor; Jackson 1958)).

Ten percent of the soil and humus samples having as wide as possible a range of values for the above parameters were selected and analyzed for available nitrogen by extraction with potassium chloride solution (Bremner and Keeney 1965), and for total phosphorus, calcium, magnesium, and potassium by the ashing method for humus samples and by the sodium fusion method for mineral soil samples (Black 1965). A final identification of all soil horizons was made on the basis of the above analyses and the field classifications were checked and soil types assigned according to specifications laid down by the National Soil Survey Committee (Anonymous 1970).

The site index, *i.e.* dominant height at a breast height age of 50 years (Page 1968), basal area, number of trees per acre, and mean annual merchantable volume increment per acre (merchantable volume to 6-in. (15.2-cm) stump and 3-in. (7.6-cm) top diameter outside bark) were calculated for the stands on each of the sample plots. Data for balsam fir and black spruce were combined because there was very little difference in their growth on each of the soil types.

Climate and Bedrock Geology of the Sample Area

Annual precipitation is heavy in both sampling areas, averaging between 50 and 60 in. (127 and 152 cm) on the Avalon Peninsula and between 35 and 55 in. (89 and 140 cm) in western Newfoundland. In comparison with most other parts of Canada summers are relatively cool (July mean temperature about 60 °F (16 °C)) and winters mild (January mean temperature 15 to 25 °F (−10 to −4 °C)), especially on the Avalon Peninsula where maritime influences are very strong (Hare 1952).

Most of the Avalon peninsula is underlain by Hadrynian slates, siltstones, and conglomerates, but Cambrian slates and Hadrynian plutonic rocks occur locally. In western Newfoundland, Cambrian and Ordovician limestones, and Carboniferous sandstones, siltstones, and conglomerates are abundant. Cambrian and Helikian gneiss and schist, Helikian gabbro and related rocks, and Devonian granite and related rocks occur locally.

Important Soil-Forming Processes in Newfoundland

Many of the soils of both sample areas have developed in glacial tills of varied depths deposited during the retreat of the ice of the Wisconsin glaciation. The tills of the Avalon Peninsula are compacted, fine-textured, and usually very stony. Bedrock outcrops are common, but less so in the forested areas than in other parts of the peninsula. In western Newfoundland the glacial tills are less compacted, less stony, and coarser-textured than those of the Avalon Peninsula. Bedrock outcrops are frequent at higher elevations.

In western Newfoundland, there are extensive lacustrine deposits around Deer Lake and large areas of sandy and gravelly outwash deposits northeast of Deer Lake and east of Stephenville. Small areas of outwash deposits are present on the Avalon Peninsula, as well as recent alluvial deposits in some of the larger river valleys.

Most soils are relatively mature. However, in alluvial materials of more recent origin active profile development appears to be still taking place. As a result of the high rainfall, leaching is a very important soil-forming process in Newfoundland, and soils of the podzolic and brunisolic orders are typical wherever drainage conditions are adequate. Leaching often occurs to a greater depth in western Newfoundland where the topography and coarser-textured parent materials favor rapid drainage; on the Avalon Peninsula the more level topography and the finer-textured tills result in the more frequent occurrence of gleysols and gleyed podzols. The high rainfall and humidity, together with the coniferous forest cover, have caused the accumulation of large amounts of surface organic material and the incorporation of relatively large amounts of organic matter into the lower parts of the profile in many

soils; deep peat deposits are common in areas of impeded drainage.

Most of the soils of both sample areas are strongly acidic, having been formed from noncalcareous parent materials. There are, however, considerable areas in western Newfoundland where the soils are less strongly acidic, having been formed from calcareous till or from shallow noncalcareous till above limestone bedrock.

Properties of the Common Soil Types

Properties of the common and important Newfoundland forest soil types, recognized on the basis of profile morphology, are summarized in Tables 1 and 2 and discussed below. For any given soil type the morphological and physical properties of the upper portion of the soil profile (*i.e.* the portion from which samples were taken) are regarded as essentially the same on calcareous and noncalcareous parent materials; a distinction is made between these two classes of parent material where necessary on the basis of chemical properties.

Orthic Sombric Brunisols[1] *(Fig. 2a)*

These are soils of the brunisolic order, characterized by a shallow, well decomposed surface organic mantle, and a well developed dark grayish-brown (10YR 3/2), humus-enriched A_h horizon which merges below with a brown (10YR 5/2 to 10YR 5/4) B_m horizon; profile drainage is usually free to moderate. Earthworms are usually present in the A_h horizon. These soils are of infrequent occurrence, formed mainly on alluvial and lacustrine materials. They are considered "young" and still developing; with a continued cover of softwood stands most of them will likely eventually develop into orthic or degraded dystric brunisols. Available nutrients are generally more abundant than in the other mineral soil types, especially in the lower part of the profile. The pH is usually relatively high in relation to other soils examined, and the carbon–nitrogen ratio low.

All forest stands recorded on soils of this type were composed predominantly of balsam fir, often with a relatively high admixture of hardwoods. The productive potential of these soils is high (see Table 3). The average site index of the stands was 41 ft (12.5 m) on the Avalon Peninsula and 47 ft (14.3 m) in western Newfoundland; basal areas averaged 118 and 215 ft²/acre (27.1 and 49.4 m²/ha) and mean annual merchantable volume increments averaged 28 and 38 ft³/acre (1.96 and 2.66 m³/ha), respectively.

Orthic and Degraded Dystric Brunisols[2] *(Fig. 2b)*

These soils, of the brunisolic order, are characterized by a fairly shallow organic mantle, underlain by a deep, yellowish-brown (10YR 5/4) B_m horizon. Typically, both A_h and A_e horizons are absent. However, some of the soils included in this type possess a very shallow and often discontinuous A_e horizon; soils with these characteristics are often classed as degraded acid brown wooded soils or minimal podzols. Dystric brunisols are fairly common in Newfoundland and are often encountered on slopes where drainage is free but not excessive. Their pH values are normally higher and carbon–nitrogen ratios lower than in the true podzols. Available nutrients are less than in the sembric brunisols, but greater than in the podzols.

Productive balsam fir stands usually occupy these soils. Site indices average 35 ft (10.7 m) on the Avalon Peninsula and 46 ft (14.0 m) in western Newfoundland (Table 3). Basal area values average 133 and 174 ft²/acre (30.6 and 39.9 m²/ha), while mean annual increments are close to 26 and 40 ft³/acre (1.82 and 2.80 m³/ha), respectively.

Orthic Podzols (Fig. 2c)

These soils, consisting of orthic ferro-humic and orthic humo-ferric podzols,[3] are typical of the podzolic order, and are of common occurrence, especially in western Newfoundland, on freely to excessively drained sites. They have a relatively shallow organic mantle over a gray (10YR 7/1 to 10YR 6/2) eluviated (A_e) mineral soil horizon of 3 to 5 in. (7.6 to 12.7 cm) in depth. The yellowish-brown (10YR 5/4) B_f horizon is usually shallower than in the sombric and dystric brunisols. Slight ortstein

[1]Acid brown forest soils or brown earths.

[2]Acid brown wooded soils.

[3]These two great groups were not separated because no differences in tree growth were observed between them.

TABLE 1. Average values for soil factors by soil type, Avalon Peninsula

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
Number of plots:	4	15	27	4	21	27	37	3	10
Depth (in.)									
L + F	0.7	1.0	1.2	1.3	1.4	1.1	1.3	1.2	2.2
H	1.8	2.0	2.5	3.2	4.8	3.3	5.3	21.5	25.1
A_e	—	(0.4)	3.3	2.2	2.8	3.1	—	—	—
A_h	9.3	(0.5)	—	—	—	—	(0.7)	—	—
B	16.8	16.5	12.1	10.7	12.0	11.3	12.1	(1.5)	(1.1)
Total soil depth	29	23	20	20	22	20	21	24	29
Profile drainage	Free to moderate	Free to moderate	Free	Free to moderate	Free	Partly impeded	Impeded	Impeded	Impeded
Depth to gleying (in.)	—	—	—	—	—	8.4	8.0	—	—
Elevation (ft)	108	409	436	407	311	344	351	437	262
% Slope	2	19	18	19	19	15	9	5	2
% Stones (by weight)									
A_h	34	—	—	—	—	—	(1)	—	—
A_e	—	—	40	—	40	33	—	—	—
B, 6 in.*	—	30	36	39	—	39	29	—	—
B, 12 in.	39	36	40	29	39	42	43	—	—
% Sand									
A_h	47	—	—	—	—	—	(25)	—	—
A_e	—	—	26	—	27	16	—	—	—
B, 6 in.	—	13	15	32	—	18	18	—	—
B, 12 in.	40	23	31	44	29	34	34	—	—
% Silt									
A_h	21	—	—	—	—	—	(36)	—	—
A_e	—	—	43	—	40	41	—	—	—
B, 6 in.	—	44	40	40	—	41	40	—	—
B, 12 in.	19	40	38	35	39	36	37	—	—
% Clay									
A_h	12	—	—	—	—	—	(17)	—	—
A_e	—	—	24	—	21	36	—	—	—
B, 6 in.	—	26	30	18	—	29	30	—	—
B, 12 in.	10	19	17	10	17	22	22	—	—
Bulk density									
H, 1 in.	0.22	0.22	0.22	0.17	0.20	0.19	0.18	0.21	0.14
H, 6 in.	—	—	—	—	—	0.19	0.22	0.21	0.14
H, 12 in.	—	—	—	—	—	—	—	0.26	0.15
A_h	0.83	—	—	—	—	—	(0.70)	—	—
A_e	—	—	1.06	—	0.96	1.04	—	—	—
B, 6 in.	—	0.76	0.83	0.92	—	0.98	0.92	—	—
B, 12 in.	1.34	0.75	0.91	1.09	0.88	1.15	1.24	—	—

TABLE 1 (*Continued*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
% Moisture at 15 atm									
H, 1 in.	86	97	99	99	108	114	103	96	121
H, 6 in.	—	—	—	—	—	73	77	77	91
H, 12 in.	—	—	—	—	—	—	—	48	81
A_h	26	—	—	—	—	—	(26)	—	—
A_e	—	—	11	—	14	11	—	—	—
B, 6 in.	—	23	19	14	—	14	14	—	—
B, 12 in.	10	19	17	11	18	11	10	—	—
% Moisture at $\frac{1}{3}$ atm									
H, 1 in.	132	319	314	258	342	351	322	302	416
H, 6 in.	—	—	—	—	—	210	210	180	291
H, 12 in.	—	—	—	—	—	—	—	163	228
A_h	72	—	—	—	—	—	(72)	—	—
A_e	—	—	45	—	58	39	—	—	—
B, 6 in.	—	74	63	53	—	57	59	—	—
B, 12 in.	31	65	56	49	54	46	42	—	—
Value									
H, 1 in.	3.0	2.8	2.6	2.3	3.1	3.0	2.8	2.7	3.6
H, 6 in.	—	—	—	—	—	3.8	3.5	2.3	2.5
H, 12 in.	—	—	—	—	—	—	—	3.3	2.6
A_h	3.7	—	—	—	—	—	(4.6)	—	—
A_e	—	—	6.2	—	6.0	6.4	—	—	—
B, 6 in.	—	5.0	5.4	5.7	—	6.0	5.4	—	—
B, 12 in.	5.0	4.8	5.1	4.7	5.1	5.6	5.9	—	—
Chroma									
H, 1 in.	2.0	2.0	1.6	2.0	2.0	1.7	1.7	2.0	1.7
H, 6 in.	—	—	—	—	—	2.0	2.1	2.0	2.0
H, 12 in.	—	—	—	—	—	—	—	2.0	1.9
A_h	1.9	—	—	—	—	—	(1.8)	—	—
A_e	—	—	1.9	—	2.1	1.9	—	—	—
B, 6 in.	—	3.5	3.3	2.3	—	2.9	2.2	—	—
B, 12 in.	2.0	3.4	3.8	3.0	3.5	2.7	2.4	—	—
pH									
H, 1 in.	4.1	3.8	3.6	3.5	3.6	3.8	3.8	4.1	4.1
H, 6 in.	—	—	—	—	—	3.4	3.7	4.4	4.3
H, 12 in.	—	—	—	—	—	—	—	5.0	4.4
A_h	4.4	—	—	—	—	—	(4.8)	—	—
A_e	—	—	4.0	—	3.9	4.2	—	—	—
B, 6 in.	—	4.5	4.3	4.2	—	4.2	4.3	—	—
B, 12 in.	4.7	4.7	4.5	4.5	4.3	4.4	4.6	—	—

TABLE 1 (*Continued*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
% Loss on ignition									
H, 1 in.	71	80	82	94	95	87	89	82	92
H, 6 in.	—	—	—	—	—	76	76	70	88
H, 12 in.	—	—	—	—	—	—	—	40	84
A_h	20	—	—	—	—	—	(22)	—	—
A_e	—	—	8	—	12	7	—	—	—
B, 6 in.	—	17	14	10	—	11	11	—	—
B, 12 in.	9	16	14	11	14	9	8	—	—
C/N ratio									
H, 1 in.	30	40	48	58	52	52	51	43	57
H, 6 in.	—	—	—	—	—	56	51	32	40
H, 12 in.	—	—	—	—	—	—	—	27	38
A_h	23	—	—	—	—	—	(28)	—	—
A_e	—	—	36	—	34	32	—	—	—
B, 6 in.	—	32	36	37	—	30	30	—	—
B, 12 in.	28	29	36	52	37	35	32	—	—
Available N (% by weight)†									
H, 1 in.	0.013	0.012	0.010	0.009	0.011	0.010	0.010	0.012	0.010
H, 6 in.	—	—	—	—	—	0.007	0.009	0.013	0.014
H, 12 in.	—	—	—	—	—	—	—	0.008	0.014
A_h	0.003	—	—	—	—	—	(0.003)	—	—
A_e	—	—	0.001	—	0.002	0.001	—	—	—
B, 6 in.	—	0.002	0.002	0.001	—	0.002	0.002	—	—
B, 12 in.	0.001	0.002	0.002	0.001	0.002	0.001	0.001	—	—
Available P (meq/100 g)									
H, 1 in.	0.289	0.209	0.199	0.148	0.229	0.251	0.236	0.116	0.137
H, 6 in.	—	—	—	—	—	0.106	0.135	0.010	0.065
H, 12 in.	—	—	—	—	—	—	—	0.005	0.027
A_h	0.006	—	—	—	—	—	(0.010)	—	—
A_e	—	—	0.018	—	0.011	0.019	—	—	—
B, 6 in.	—	0.005	0.010	0.011	—	0.016	0.014	—	—
B, 12 in.	0.011	0.005	0.009	0.010	0.005	0.010	0.009	—	—
Available Ca (meq/100 g)									
H, 1 in.	4.30	4.61	3.62	4.17	4.54	7.02	5.60	5.60	12.60
H, 6 in.	—	—	—	—	—	3.23	2.76	5.00	10.94
H, 12 in.	—	—	—	—	—	—	—	5.18	9.34
A_h	0.83	—	—	—	—	—	(1.32)	—	—
A_e	—	—	0.12	—	0.15	0.30	—	—	—
B, 6 in.	—	0.30	0.16	0.13	—	0.36	1.22	—	—
B, 12 in.	0.42	0.21	0.11	0.07	0.11	0.23	0.49	—	—

TABLE 1 (*Concluded*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
Available Mg (meq/100 g)									
H, 1 in.	2.71	4.77	4.79	5.91	4.97	5.62	5.07	4.98	8.49
H, 6 in.	—	—	—	—	—	5.53	5.08	2.72	6.51
H, 12 in.	—	—	—	—	—	—	—	2.18	6.67
A_h	0.91	—	—	—	—	—	(0.97)	—	—
A_e	—	—	0.31	—	0.46	0.41	—	—	—
B, 6 in.	—	0.43	0.31	0.23	—	0.48	0.89	—	—
B, 12 in.	0.45	0.21	0.17	0.10	0.24	0.32	0.35	—	—
Available K (meq/100 g)									
H, 1 in.	1.39	1.70	1.49	1.68	1.67	1.93	1.80	1.74	1.45
H, 6 in.	—	—	—	—	—	1.10	0.91	1.03	0.44
H, 12 in.	—	—	—	—	—	—	—	0.80	0.23
A_h	0.21	—	—	—	—	—	(0.20)	—	—
A_e	—	—	0.07	—	0.11	0.08	—	—	—
B, 6 in.	—	0.15	0.09	0.08	—	0.10	0.13	—	—
B, 12 in.	0.05	0.09	0.08	0.04	0.07	0.07	0.07	—	—
Available Na (meq/100 g)									
H, 1 in.	1.53	1.16	1.27	1.80	1.52	1.62	1.43	1.39	1.52
H, 6 in.	—	—	—	—	—	1.57	1.13	1.04	1.05
H, 12 in.	—	—	—	—	—	—	—	0.69	0.94
A_h	0.33	—	—	—	—	—	(0.33)	—	—
A_e	—	—	0.15	—	0.22	0.15	—	—	—
B, 6 in.	—	0.22	0.15	0.11	—	0.17	0.24	—	—
B, 12 in.	0.26	0.16	0.15	0.07	0.18	0.13	0.14	—	—

*Figures in inches refer to the depth below the upper surface of the H layer at which the samples were collected.
†Based on 10% subsample.

TABLE 2. Average values for soil factors by soil type, western Newfoundland

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
Number of plots:	3	15	42	8	24	10	22	7	19
Depth (inches)									
L + F	0.8	1.1	1.2	1.3	1.5	1.7	1.5	1.7	2.0
H	1.5	2.4	2.4	2.9	5.5	4.5	5.3	16.4	24.4
A_h	3.0	—	—	—	—	—	—	—	—
A_e	—	(0.7)	4.8	2.3	2.9	2.6	—	—	—
B	21.3	17.1	15.3	16.1	13.7	13.6	21.4	12.6	6.5
Total soil depth	36+	29	26	27	26	23	30	31	34
Profile drainage	Moderate	Free to moderate	Free	Free to moderate	Free	Partly impeded	Impeded	Impeded	Impeded
Depth to gleying (in.)	—	—	—	—	—	8.9	7.8	17.3	17.8
Elevation (ft)	433	412	478	405	380	777	576	534	447
% Slope	6	17	13	13	13	19	8	7	5
% Stones (by weight)									
A_h	0	—	—	—	—	—	—	—	—
A_e	—	—	32	13	23	26	—	—	—
B, 6 in.*	15	26	24	38	21	—	19	—	—
B, 12 in.	27	22	31	26	29	32	23	—	—
% Sand									
A_h	25	—	—	—	—	—	—	—	—
A_e	—	—	57	41	46	34	—	—	—
B, 6 in.	37	31	38	35	50	—	41	—	—
B, 12 in.	64	38	48	39	44	36	44	—	—
% Silt									
A_h	20	—	—	—	—	—	—	—	—
A_e	—	—	33	45	35	44	—	—	—
B, 6 in.	41	40	41	39	34	—	40	—	—
B, 12 in.	24	35	34	39	34	43	38	—	—
% Clay									
A_h	6	—	—	—	—	—	—	—	—
A_e	—	—	8	9	10	17	—	—	—
B, 6 in.	13	20	13	9	7	—	12	—	—
B, 12 in.	8	19	11	9	10	13	13	—	—
Bulk density									
H, 1 in.	0.49	0.24	0.24	0.24	0.22	0.19	0.22	0.18	0.21
H, 6 in.	—	—	—	—	0.28	0.20	0.25	0.22	0.19
H, 12 in.	—	—	—	—	—	—	—	0.25	0.20
A_h	0.33	—	—	—	—	—	—	—	—
A_e	—	—	1.35	1.31	1.16	1.19	—	—	—
B, 6 in.	0.96	1.03	1.14	0.93	0.96	—	1.11	—	—
B, 12 in.	1.34	1.11	1.24	1.05	1.04	1.15	1.32	—	—

TABLE 2 (*Continued*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
% Moisture at 15 atm									
H, 1 in.	54	95	85	91	92	102	93	122	90
H, 6 in.	—	—	—	—	81	83	80	107	87
H, 12 in.	—	—	—	—	—	—	—	94	83
A_h	60	—	—	—	—	—	—	—	—
A_e	—	—	3	3	8	5	—	—	—
B, 6 in.	8	10	7	16	7	—	4	—	—
B, 12 in.	7	9	6	10	11	7	6	—	—
% Moisture at $\frac{1}{3}$ atm									
H, 1 in.	125	271	259	289	303	335	301	316	363
H, 6 in.	—	—	—	—	245	215	232	252	329
H, 12 in.	—	—	—	—	—	—	—	212	259
A_h	161	—	—	—	—	—	—	—	—
A_e	—	—	23	46	37	36	—	—	—
B, 6 in.	43	45	39	47	28	—	35	—	—
B, 12 in.	32	40	34	48	42	39	33	—	—
Value									
H, 1 in.	2.5	2.9	3.0	2.9	2.8	2.8	2.8	2.3	3.1
H, 6 in.	—	—	—	—	3.0	3.3	2.6	2.1	2.6
H, 12 in.	—	—	—	—	—	—	—	2.0	2.5
A_h	3.0	—	—	—	—	—	—	—	—
A_e	—	—	6.5	6.3	5.8	5.5	—	—	—
B, 6 in.	4.0	5.1	5.5	5.0	4.0	—	5.6	—	—
B, 12 in.	4.0	5.0	5.3	4.6	4.6	5.0	5.5	—	—
Chroma									
H, 1 in.	2.0	1.9	1.9	1.9	1.9	1.8	2.0	1.6	2.0
H, 6 in.	—	—	—	—	1.9	1.7	1.8	2.0	2.1
H, 12 in.	—	—	—	—	—	—	—	1.4	1.9
A_h	2.0	—	—	—	—	—	—	—	—
A_e	—	—	1.6	1.7	1.9	2.3	—	—	—
B, 6 in.	3.5	3.9	3.2	3.0	3.0	—	2.6	—	—
B, 12 in.	3.5	4.1	3.8	3.0	3.6	2.8	2.6	—	—
pH									
H, 1 in.	4.8	4.1	3.8	3.6	3.6	3.6	4.2	4.8	3.7
H, 6 in.	—	—	—	—	3.3	3.3	5.3	5.1	3.9
H, 12 in.	—	—	—	—	—	—	—	5.4	4.2
A_h	5.2	—	—	—	—	—	—	—	—
A_e	—	—	3.9	4.2	4.0	3.7	—	—	—
B, 6 in.	6.0	4.8	4.2	4.4	3.9	—	4.6	—	—
B, 12 in.	5.5	5.2	4.7	5.0	4.5	4.3	5.4	—	—

TABLE 2 (*Continued*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
% Loss on ignition									
H, 1 in.	56	87	88	92	95	95	92	93	96
H, 6 in.	—	—	—	—	86	84	69	87	95
H, 12 in.	—	—	—	—	—	—	—	82	92
A_h	49	—	—	—	—	—	—	—	—
A_e	—	—	3	5	9	6	—	—	—
B, 6 in.	10	9	8	17	10	—	6	—	—
B, 12 in.	5	7	7	13	12	8	5	—	—
C/N ratio									
H, 1 in.	32	42	51	45	53	58	48	43	58
H, 6 in.	—	—	—	—	62	61	35	37	53
H, 12 in.	—	—	—	—	—	—	—	31	46
A_h	28	—	—	—	—	—	—	—	—
A_e	—	—	31	35	44	37	—	—	—
B, 6 in.	21	37	35	51	40	—	26	—	—
B, 12 in.	22	42	38	50	42	38	29	—	—
Available N (% by weight)†									
H, 1 in.	0.005	0.006	0.005	0.006	0.005	0.005	0.006	0.007	0.005
H, 6 in.	—	—	—	—	0.004	0.004	0.006	0.008	0.006
H, 12 in.	—	—	—	—	—	—	—	0.008	0.006
A_h	0.016	—	—	—	—	—	—	—	—
A_e	—	—	0.001	0.001	0.001	0.001	—	—	—
B, 6 in.	0.004	0.002	0.002	0.003	0.002	—	0.002	—	—
B, 12 in.	0.002	0.002	0.002	0.002	0.003	0.002	0.002	—	—
Available P (meq/100 g)									
H, 1 in.	1.625	0.239	0.265	0.301	0.227	0.293	0.188	0.192	0.154
H, 6 in.	—	—	—	—	0.134	0.110	0.106	0.065	0.102
H, 12 in.	—	—	—	—	—	—	—	0.045	0.073
A_h	0.147	—	—	—	—	—	—	—	—
A_e	—	—	0.009	0.007	0.009	0.006	—	—	—
B, 6 in.	0.004	0.004	0.004	0.001	0.002	—	0.008	—	—
B, 12 in.	0.004	0.008	0.003	0.002	0.004	0.004	0.023	—	—
Available Ca (meq/100 g)									
H, 1 in.	23.50	15.13	8.84	8.49	9.19	7.23	24.60	50.61	16.10
H, 6 in.	—	—	—	—	4.24	6.37	44.36	71.09	28.85
H, 12 in.	—	—	—	—	—	—	—	93.50	37.83
A_h	16.25	—	—	—	—	—	—	—	—
A_e	—	—	0.18	1.42	0.57	0.11	—	—	—
B, 6 in.	13.10	1.64	0.41	0.10	0.12	—	1.02	—	—
B, 12 in.	4.37	1.96	0.53	7.68	0.46	0.75	3.13	—	—

TABLE 2 (*Concluded*)

	Sombric brunisol	Dystric brunisol	Orthic podzol	Humic podzol	Peaty podzol	Gleyed podzol	Orthic gleysol	Fen peat	Acid peat
Available Mg (meq/100 g)									
H, 1 in.	3.10	7.20	3.60	5.36	4.70	4.94	5.72	7.49	5.42
H, 6 in.	—	—	—	—	4.06	7.73	6.15	8.45	6.20
H, 12 in.	—	—	—	—	—	—	—	9.44	5.96
A_h	2.38	—	—	—	—	—	—	—	—
A_e	—	—	0.18	0.26	0.62	0.20	—	—	—
B, 6 in.	1.43	1.27	0.32	0.16	0.19	—	0.34	—	—
B, 12 in.	0.90	0.78	0.35	0.46	0.44	0.33	0.46	—	—
Available K (meq/100 g)									
H, 1 in.	1.24	1.63	1.98	1.89	1.87	2.19	1.83	1.57	1.70
H, 6 in.	—	—	—	—	0.51	1.04	0.56	0.51	0.73
H, 12 in.	—	—	—	—	—	—	—	0.29	0.50
A_h	0.80	—	—	—	—	—	—	—	—
A_e	—	—	0.04	0.04	0.10	0.04	—	—	—
B, 6 in.	0.16	0.12	0.07	0.06	0.06	—	0.05	—	—
B, 12 in.	0.08	0.14	0.07	0.04	0.08	0.04	0.05	—	—
Available Na (meq/100 g)									
H, 1 in.	0.41	0.74	0.64	1.01	1.11	0.86	0.89	0.72	0.84
H, 6 in.	—	—	—	—	0.85	1.34	0.62	0.74	0.92
H, 12 in.	—	—	—	—	—	—	—	0.70	0.83
A_h	0.64	—	—	—	—	—	—	—	—
A_e	—	—	0.08	0.18	0.19	0.08	—	—	—
B, 6 in	0.28	0.15	0.12	0.12	0.14	—	0.10	—	—
B, 12 in.	0.23	0.15	0.10	0.17	0.19	0.10	0.09	—	—

*Figures in inches refer to the depth below the upper surface of the H layer at which the samples were collected.
†Based on 10% subsample.

TABLE 3. Average values for stand parameters (balsam fir and black spruce combined) by soil type on the Avalon Peninsula and in western Newfoundland

	Site index (ft)		Basal area (ft^2/acre)		Mean annual merchantable volume increment (ft^3/acre)		Number of trees per acre	
Soil type	Avalon	Western	Avalon	Western	Avalon	Western	Avalon	Western
Orthic sombric brunisol	41.3	47.3	117.8	214.6	27.8	37.8	1670	1757
Orthic and degraded brunisol	34.8	45.9	132.8	174.4	25.7	40.2	2258	1478
Orthic podzol	31.7	42.4	124.3	154.0	23.3	31.3	2128	1941
Orthic humic podzol	30.9	39.5	110.7	137.3	16.1	25.9	1617	1300
Peaty podzol	33.7	35.3	122.9	127.1	20.3	20.5	1916	1661
Gleyed podzol	26.5	33.5	100.9	109.7	15.1	15.2	2004	1183
Orthic gleysol	28.3	33.5	102.2	113.2	14.6	18.8	2122	1435
Fen peat	22.9	26.8	81.6	89.8	10.0	9.5	2700	1623
Acid peat	22.7	25.9	57.3	79.4	5.5	7.7	1464	1444

development is present in the upper part of the B horizon in some of these soils; true hardpan development is, however, rare. Soils of this type are usually very acid, low in available nutrients, and have high carbon–nitrogen ratios. There is a low organic matter content in the mineral soil horizons.

Stands of balsam fir and black spruce are common on these soils. Site index values average 32 ft (9.8 m) on the Avalon Peninsula and 42 ft (12.8 m) in western Newfoundland (Table 3). Corresponding values for basal area are 124 and 154 ft^2/acre (28.5 and 35.4 m^2/ha), and for mean annual increment 23 and 31 ft^3/acre (1.61 and 2.17 m^3/ha).

Orthic Humic Podzols (Fig. 2d)

Soils of this type are characterized by a dark-brown (10YR 4/3 to 10YR 5/3), humus-enriched upper B horizon, sometimes underlain by a lower B horizon (10YR 5/3) enriched with iron. Soils were classed as belonging to this type only if the H layer was less than 4 in. (10 cm) thick; podzols with a greater depth of surface organic matter (either with or without a humus-enriched B horizon) appeared to give a different response in terms of tree growth and were classed separately as peaty podzols (see below). For the orthic humic podzols, the average depth of the L and F layers is 1.3 in. (3.3 cm) and of the H layer 3 in. (7.6 cm); the gray (10YR 6/2) A_e horizon is usually shallower than in the orthic podzols. These soils are acid, with high carbon–nitrogen ratios and relatively low available nutrient contents.

Balsam fir and black spruce stands average 31 ft (9.5 m) site index on the Avalon Peninsula and 40 ft (12.2 m) in western Newfoundland (Table 3). Average basal area figures are 111 and 137 ft^2/acre (25.5 and 31.5 m^2/ha), and average mean annual increments are 16 and 26 ft^3/acre (1.12 and 1.82 m^3/ha).

Peaty Podzols[4] (Fig. 2e)

Soils of this type have a relatively deep organic mantle (H layer in excess of 4 in. (10 cm)) above a gray (10YR 6/2) A_e horizon of 2 to 3 in. (5.1 to 7.6 cm) in depth and a brown or yellow-brown (10YR 5/3 to 10YR 4/4) B horizon enriched with iron and usually humus as well. Drainage is sufficiently free to induce podzolization, but at the same time sites are sufficiently moist to permit the accumulation of relatively large amounts of surface organic matter. On the average, these soils are more acid than those of any other type examined. Their carbon–nitrogen ratios are high, and their available nutrient status relatively low. Organic matter content of the A_e and B horizons is usually higher than that of any other soils of the podzolic order except the orthic humic podzols.

[4]This type is not defined as a separate subgroup by the National Soil Survey Committee of Canada (Anonymous 1970). It consists of peaty phases of all three great groups within the podzolic order.

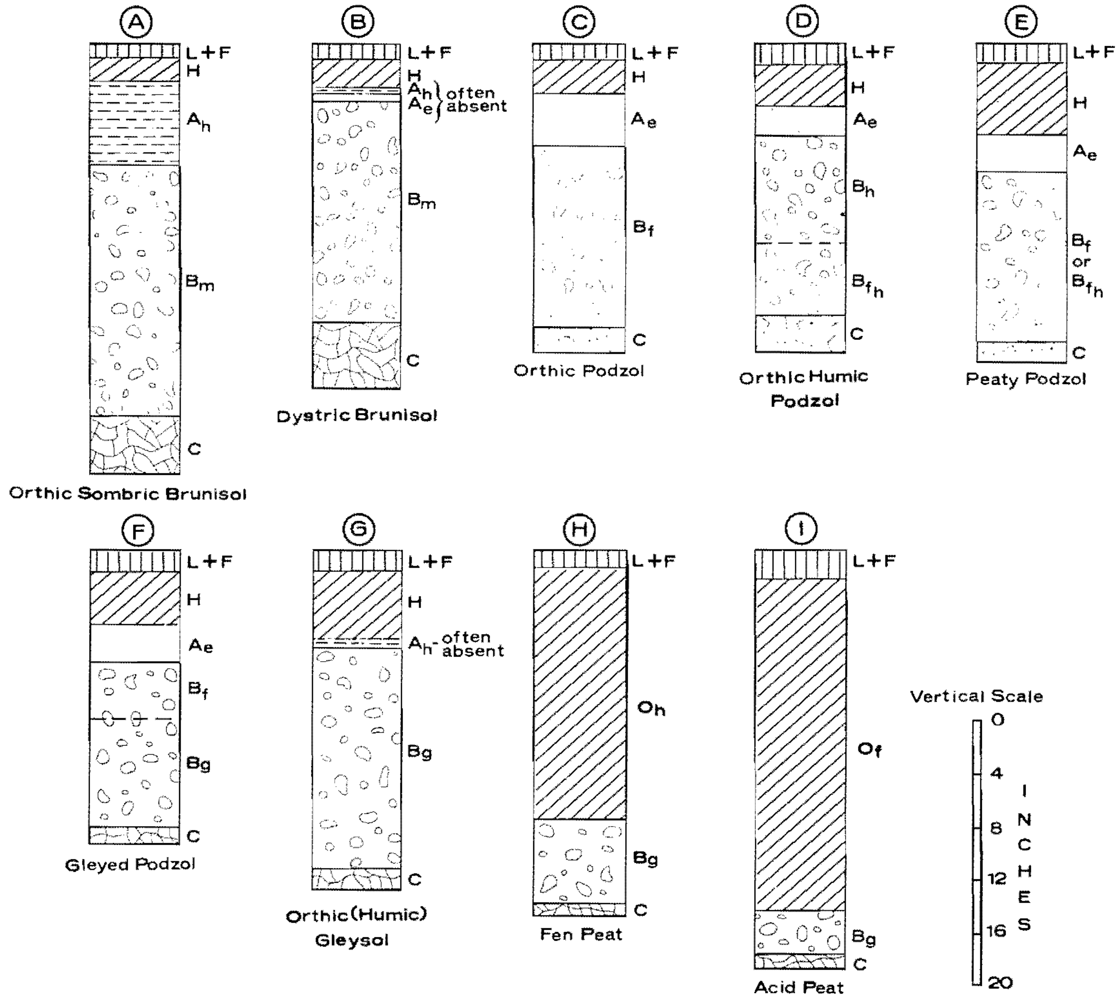

FIG. 2. Typical profiles of nine common Newfoundland forest soil types.

The peaty podzols are moderately productive soils, carrying stands of balsam fir and black spruce. Site index values average 34 ft (10.4 m) on the Avalon Peninsula and 35 ft (10.7 m) in western Newfoundland (Table 3). Corresponding values for basal area are 123 and 127 ft²/acre (28.2 and 29.2 m²/ha); mean annual increments average 20 ft³/acre (1.4 m³/ha) in both sample areas.

Gleyed Podzols[5] *(Fig. 2f)*

These soils, which are gleyed members of the podzolic order, occur where drainage is partly impeded in the lower part of the profile, but sufficiently free in the upper part to permit the development of an A_e horizon. They are common on the Avalon Peninsula, but of less frequent occurrence in western Newfoundland. There is usually a moderately deep organic mantle over a gray (10YR 6/2) A_e horizon which averages 2 to 3 in. (5.1 to 7.6 cm) in depth. Gleying may be present throughout the B horizon, but more usually there is a shallow pale brown (10YR 6/3) B_f horizon above a deeper, pale grayish-brown (10YR 5/2 to 10YR 5/3), mottled B_g horizon. The gleyed podzols are strongly acid, with high carbon–nitrogen ratios. Organic matter content of the

[5]Gleyed ferro-humic and gleyed humo-ferric podzols.

mineral soil horizons is usually less than that of the other podzol soil types. Available nutrient status is usually a little better than that of the other podzol types, but nevertheless relatively low; total nitrogen content is lower than that of most other soil types.

On the Avalon Peninsula, the site index of balsam fir and black spruce stands averages 27 ft (8.2 m) (Table 3). Basal area is about 101 ft^2/acre (23.2 m^2/ha), and mean annual increment about 15 ft^3/acre (1.05 m^3/ha). In western Newfoundland, site index is about 34 ft (10.4 m), basal area about 110 ft^2/acre (25.3 m^2/ha) and mean annual increment about 15 ft^3/acre (1.05 m^3/ha).

Orthic Gleysols (Fig. 2g)

These members of the gleysolic order are common in Newfoundland, especially on the Avalon Peninsula. Orthic humic gleysols, with a relatively deep organic mantle (including an H layer of more than 4 in. (10 cm)) are the most frequently encountered, but orthic gleysols with only a shallow organic mantle have also been recorded. There is a gray-brown (10YR 5/2 to 10YR 6/3) B horizon beneath the organic mantle. The boundary between the organic and mineral soil layers is usually fairly distinct, but in some cases, especially where the organic material is very well decomposed, there is a well marked mineral–organic transition zone (A_h horizon). Gleysols may develop where fine-textured, compacted tills occur on areas of relatively level topography, so preventing adequate drainage through the profile. They may also develop in soils of any texture on lower slopes where there is an abundant supply of seepage water. Available nutrient contents (except nitrogen and phosphorus) and pH values are a little higher, and C/N ratios somewhat lower, than in the podzols, and similar to the dystric brunisols. Only small amounts of organic matter are incorporated into the B horizon.

Balsam fir and black spruce stands occur on these soils, although the latter are more common. Site index values average 28 and 34 ft (8.5 and 10.4 m), basal areas average 102 and 113 ft^2/acre (23.4 and 26.0 m^2/ha), and mean annual increments average 15 and 19 ft^3/acre (1.05 and 1.33 m^3/ha), on the Avalon Peninsula and in western Newfoundland, respectively (Table 3).

Fen Peats[6] (Fig. 2h)

Soils of this type are characterized by a well decomposed lower organic layer (O_h or O_m) more than 12 in. (30 cm) deep, overlaying gleyed mineral soil or, occasionally, bedrock. The lower part of the organic horizon often contains an admixture of fine mineral soil particles. These soils have a high base status, relatively high pH values, and fairly low carbon–nitrogen ratios. Nitrogen content is high in comparison with many of the other soil types, but available phosphorus is often very low. Fen peats are of fairly frequent occurrence in western Newfoundland, usually in association with calcareous bedrock; they are rare on the Avalon Peninsula, where there are few rocks of high base status.

These soils usually support balsam fir stands or, more rarely, black spruce stands. Site index values average 23 ft (7.0 m) on the Avalon Peninsula and 27 ft (8.2 m) in western Newfoundland (Table 3); corresponding values for basal area are 82 and 90 ft^2/acre (18.8 and 20.7 m^2/ha). Mean annual increments average 10 ft^3/acre (0.7 m^3/ha) in both sample areas.

Acid Peats[7] (Fig. 2i)

Acid peats possess deep L and F layers, and poorly decomposed lower organic layers (O_f or O_m) of more than 12 in. (30 cm) (and often many feet) in depth. Gleyed mineral soil is present beneath some of the shallower peats. Acid peats may form in depressions (basin bogs) or on upland areas (blanket bogs) where internal drainage is very poor. Moisture retention capacity is very high, especially in the less decomposed material near the surface. Carbon–nitrogen ratios are high, and pH values low, although not usually as low as in the organic mantle of the podzol types. The content of most nutrients, except nitrogen and phosphorus, is usually high in comparison with most of the mineral soil types.

Forest stands on acid peats are usually very open and composed predominantly of black spruce. Site indices on the Avalon Peninsula average 23 ft (7.0 m) and in western Newfoundland 26 ft (7.9 m) (Table 3). Basal areas in the two sample regions average 57 and 79 ft^2/acre (13.1 and 18.2 m^2/ha) and

[6]Eutrophic peats.
[7]Oligotrophic and mesotrophic peats.

mean annual increments average 6 and 8 ft^3/acre (0.4 and 0.6 m^3/ha).

Some Comparisons between the Soil Types

The properties of the nine soil types examined in this paper reveal a number of broad differences between the two sample areas, and also consistent relationships between the types within each of the two areas.

The parent materials of the Avalon Peninsula are stonier, more compacted, and richer in silt and clay than those of western Newfoundland. In addition, rainfall is higher and topography less varied on the Avalon Peninsula. As a result, gleysols, gleyed podzols, and acid peats are more common on the Avalon Peninsula than in western Newfoundland, while the reverse is true for the podzols. There are very few rocks of high base status on the Avalon Peninsula and, as a consequence, fen peats are rare, and calcium and magnesium contents, together with pH values, are lower in all soils than in western Newfoundland. Organic matter decomposition is generally better in western Newfoundland and this may be the cause of the observed higher surface bulk density readings and lower moisture retention capacities. In addition, profile development of the soils of western Newfoundland is, on the average, deeper than that of the Avalon Peninsula soils.

Despite these overall differences between the two sample areas, relationships between the soil types are essentially the same in both areas. There is a progressively increasing depth of surface organic matter through the series sombric brunisols, dystric brunisols, orthic podzols, humic and peaty podzols, gleysols, and fen peats, to acid peats. The B horizon depth is usually greatest in the brunisols, intermediate in the podzols and gleysols, and least in the deep peat soils. Total soil depth is greatest in the sombric brunisols and peats and least in the podzols and gleysols.

Profile drainage is usually free to excessive in the podzols, free to moderate in the brunisols, and partly or totally impeded in the gleysols and peats. Sand content is usually highest and clay content lowest in the sombric brunisols. The gleyed soils often have a rather higher clay content and lower sand content than the podzols, but overall differences are small. Stone content varies little between the types. Where organic matter decomposition is most rapid (*i.e.* in the brunisols, orthic podzols, and fen peats) surface bulk density values are a little higher and moisture retention capacities a little lower than in those soil types where decomposition is slow. The A_e horizon of the podzols normally has a higher bulk density value than the B horizôn immediately beneath. This reflects the lower organic matter content, and hence also lower moisture retention capacity, of the A_e horizon. The incorporation of organic material into the lower mineral soil horizons is greatest in the podzols and dystric brunisols and least in the gleysols.

The lowest pH values are associated with the podzols and, to a lesser extent, the acid peats. The dystric brunisols and gleysols are intermediate in terms of pH values, while the sombric brunisols and fen peats have the highest values. Carbon–nitrogen ratios are relatively low in the sombric brunisols, somewhat higher in the dystric brunisols and fen peats, and very high in the other types.

Total nitrogen content in the upper part of the profile is usually highest in the brunisols and fen peats. The organic soils contain much more nitrogen per unit weight in the lower parts of the profile than do the mineral soils. On a per acre basis, the sombric brunisols and peats contain an average of 6000 to 7000 lb (6750 to 7850 kg/ha) of nitrogen in the upper 12 in. (30 cm), while the podzols contain only 3000 to 4000 lb (3350 to 4500 kg). In most cases (see Table 4) less than 1% of the total nitrogen supply is in an available form and, on the average, between 25 and 60 lb of nitrogen per acre (28 and 67 kg/ha) are available at any given time for tree growth in the various soil types.

Available phosphorus contents are highest in the sombric brunisols and lowest in the peats, but differences between the soil types are generally small. The total phosphorus content (Table 4) in the upper 12 in. (30 cm) averages from 900 to 1300 lb/acre (1000 to 1450 kg/ha) for all soil types. Only about 15 lb/acre (17 kg/ha) of this total are in an available form.

Available calcium and magnesium contents are usually higher in the poorly drained soils than in the freely drained soils, and also higher in western Newfoundland than on the Avalon Peninsula, especially in regard to those soil

TABLE 4. Average contents of total nitrogen, phosphorus, calcium, magnesium, and potassium in humus and mineral soil (all soil types), and relationships between total and available nutrients

Nutrient element	Soil medium	Sample area	Average reading (all soil types)	Available nutrient as percent of total present
Total nitrogen	Humus	Avalon Peninsula	1.2%	0.9
		Western Nfld.	1.2%	0.5
	Mineral soil	Avalon Peninsula	0.2%	0.7
		Western Nfld.	0.1%	1.5
Total phosphorus*	Humus	Avalon Peninsula	3.6 meq/100g	3.2
		Western Nfld.	2.6 meq/100g	5.6
	Mineral soil	Avalon Peninsula	2.2 meq/100g	0.2
		Western Nfld.	1.5 meq/100g	0.5
Total calcium*	Humus	Avalon Peninsula	12.1 meq/100g	89.5
		Western Nfld.	71.4 meq/100g	68.7
	Mineral soil	Avalon Peninsula	11.4 meq/100g	1.4
		Western Nfld.	42.3 meq/100g	11.9
Total magnesium*	Humus	Avalon Peninsula	9.1 meq/100g	58.2
		Western Nfld.	12.1 meq/100g	61.4
	Mineral soil	Avalon Peninsula	32.1 meq/100g	0.9
		Western Nfld.	58.4 meq/100g	2.4
Total potassium*	Humus	Avalon Peninsula	3.7 meq/100g	25.3
		Western Nfld.	2.7 meq/100g	42.7
	Mineral soil	Avalon Peninsula	18.0 meq/100g	0.5
		Western Nfld.	27.6 meq/100g	0.5

*Average based on 10% subsample only.

types such as fen peats which are commonly associated with calcareous materials. Total calcium contents in the upper 12 in. (30 cm) average 3500 lb/acre (3900 kg/ha) in soils with noncalcareous parent materials, and up to 20 000 lb/acre (22 500 kg/ha) or more in soils influenced by calcareous rocks. Available calcium in the upper 12 in. (30 cm) ranges from about 200 up to 10 000 lb/acre (225 to 11 200 kg/ha) or more. There are usually between 4000 and 8000 lb/acre (4500 and 9000 kg/ha) of magnesium in the upper 12 in. (30 cm); an average of about 100 to 200 lb/acre (110 to 220 kg/ha) are in an available form.

Total potassium contents average between 10 000 and 12 000 lb/acre (11 200 and 13 500 kg/ha) in the upper 12 in. with about 150 to 200 lb/acre (170 to 225 kg/ha) in an available form. There is little difference between the soil types in terms of either available potassium or available sodium contents.

Significance of Soil Properties to Forest Growth

In general, the sombric and dystric brunisols, which are moderately to freely drained but not strongly leached and without large surface accumulations of organic matter, are associated with the best height and volume growth of the forest stands in both sample areas. The orthic, humic, and peaty podzols, which are often dry, strongly leached, and with moderately large accumulations of surface organic matter, are associated with moderate growth. The poorest tree growth occurs on the gleysols and peats, where drainage is impeded and large amounts of organic matter have accumulated. Overall differences in forest productivity between the two sample areas are probably due to the more severe wind exposure and poorer drainage conditions (resulting from the more level topography, and stony, finer textured parent materials) on the Avalon Peninsula as compared with western Newfoundland.

These results are supported by results of an earlier series of studies carried out by the author,[8] in which all the soil properties discussed in this paper were shown to be related to the growth of balsam fir and black spruce in one or both of the sample areas. Soil drainage

[8]Page, G. Canadian Forestry Service, Department of Fisheries and Forestry, Newfoundland Region: Unpublished Internal Reports N-8 (1969); N-20 (1969); N-21 (1970); N-24 (1970); N-34 (1970); and N-37 (1970).

and aeration conditions, organic matter accumulation both on the surface and within the profile, and moisture retention characteristics appeared to be of major significance to forest growth across a wide range of sites. Available nutrient supply appeared to be limiting to tree growth on some of the better sites where physical soil conditions were generally favorable.

Total soil nutrient contents reported in this paper are similar to those quoted for soils in several other parts of northern North America and northern Europe (*e.g.* Tamm 1950; Weetman 1961; Ball 1963; Heilman 1968). Available nutrient contents (especially nitrogen and phosphorus) are low in all soil types, but freely drained soils are worse in this respect than poorly drained soils. It would appear that available nutrients in poorly drained soils are adequate to maintain growth within the limits imposed by physical soil conditions. Where physical soil conditions are more favorable to growth, the supply of each of the available nutrients may have a direct limiting effect on growth.

Amounts of available nutrients reported to be necessary to maintain the nutrient budgets of forested ecosystems are relatively small (*e.g.* Weetman 1961; Ovington 1962; Cole and Gessel 1963; Likens *et al.* 1967). On sites, such as those examined in this study, where forest has been present more or less continuously since the last ice age, the nutrient cycle is usually considered to be in dynamic equilibrium, with additional supplies of nutrients from the atmosphere, litter fall, and geochemical weathering being sufficient to counteract losses to the system through leaching, volatilization, and uptake by vegetation (Lee 1968). Data for the Newfoundland forest soils examined in this paper suggest that nutrient supply is adequate to sustain the nutrient cycle and associated forest growth at their present levels almost indefinitely, regardless of whether the supply of available nutrients is acting directly as a limiting factor to growth or not. However, further, more detailed researches into the cycling of nutrients in Newfoundland forest sites are necessary to refine and extend present knowledge of nutrient availability and of possible effects on the nutrient cycle of severe disturbance involving the permanent removal of part of the nutrient supply.

The rate of nutrient cycling is associated with the rate of growth of the forest stands, and, for any given site, is dependent upon a balance of local climatic, soil, and vegetative cover conditions. Future research into methods of achieving lasting increases in forest productivity will need to examine ways of speeding up the nutrient cycle by improving microbiological and chemical activity. Several techniques of site amelioration and stand manipulation appear promising for this purpose, including mechanical mixing of surface organic material and soil, thinning of stands to increase surface soil temperatures during the growing season, and the favoring of tree species such as hardwoods having more readily decomposable litter.

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